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Research Article

Omer Farooq*

The Effect of Elaborative Interrogation on the Synthesis of Ideas from Multiple Sources of Information

Abstract: The new Framework for Information Literacy for Higher Education (ACRL, 2016) highlights the ability to synthesize ideas from multiple sources of information as one of the key knowledge practices. There is little generalizable empirical research based on cognitive science principles to guide information literacy instruction practice. The present study examined the effectiveness of elaborative interrogation instructional strategy on integration and transformation of ideas from multiple sources of information. 86 participants took part in the study via Amazon Mechanical Turk platform. The experiment involved reading five texts on the topic of climate change and responding to embedded elaborative interrogation prompts (treatment groups only), and writing a synthesis paragraph on the topic. Two one-way ANCOVAs were employed to test the hypotheses which indicated that elaborative interrogation prompts did not significantly improve performance on transformation and integration measures. This study contributes to the growing body of literature addressing information literacy instruction based on the new Framework and provides a promising long-term cross-disciplinary research partnership in terms of linking evidence-based guidance for instruction based on cognitive science principles to information literacy knowledge practices in the new Framework.

Keywords: Information literacy, multiple documents, elaborative interrogation, instructional strategies

1 Introduction

As the information landscape has expanded in the last few decades, students face the ever challenging tasks of navigating a complex, disorderly landscape as well as synthesizing ideas from multiple sources of information. The current predominant model of information literacy instruction in academic libraries, however, mainly focuses on how to find relevant information sources for their academic information needs but overlooks how students use gathered information sources to synthesize ideas. The Association of College and Research Libraries' (ACRL) Framework for Information Literacy for Higher Education (ACRL, 2016) highlights the ability to synthesize ideas from multiple sources of information as one of the key knowledge practices through which students show their development.

The body of literature on information literacy instruction is vast. However, generalizable empirical research on information literacy instruction built on the theoretical foundations of cognitive science is very limited. An integral missing segment in this body of literature is the connection between what cognitive and learning science research tells us about how students acquire these skills and in turn, how instructional librarians can best adopt findings from cognitive science regarding learning to create effective instructional techniques (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), which improve comprehension, and

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synthesis of ideas from multiple documents into their practice (Perfetti, Rouet, & Britt, 1999; Wiley & Voss, 1999).

Elaborative interrogation strategy involves prompting learners to generate an explanation for an explicitly stated fact. The primary cognitive mechanism that accounts for the effect of elaborative questioning is that it enhances learning by facilitating the integration of new information with learners' existing prior knowledge (Dunlosky et al., 2013). The cognitive benefits of explanations extend beyond integration of new material and help learners with organization and retrieval—making this instructional strategy particularly beneficial for the higher order cognitive learning tasks such as integration and transformation of ideas gathered from multiple information sources.

The purpose of this experimental study is to examine the effectiveness of elaborative interrogation instructional strategy on learners' ability to integrate and transform ideas gathered from multiple sources of information. The primary research questions guiding this study are:

Research Question 1: Do elaborative interrogation prompts improve transformation of ideas gathered from multiple sources of information?

Hypothesis 1: Participants who receive elaborative prompts would perform better on transformation measure.

Research Question 2: Do elaborative interrogation prompts improve integration of ideas gathered from multiple sources of information?

Hypothesis 2: Participants who receive elaborative prompts would perform better on integration measure.

2 Literature Review

Elaborative interrogation is a learning strategy that highlights the cognitive benefits of explanation and involves prompting learners to generate an explanation for an explicitly stated fact. The explanatory prompts differ in terms of specificity across studies—for example, the prompts include questions such as "Why is this true?" "Why does it make sense," to simply "Why?" (Dunlosky et al., 2013). Hannon (2012) defines elaborations as "any type of enhancements that clarify the original to-be-remembered information with respect to other information" (p. 299). Elaborations can be instructor-generated explanations, analogies, or examples embedded in a text with cognitive prompts such as "Which examples can you think of that illustrate, confirm your interpretations?" Elaborations are also learner-generated personal examples or restatements of important features of concepts (Hannon, 2012). An instructional strategy similar to elaborative interrogation is self-explanation.

There is considerable evidence for the cognitive benefits of explanations. Research suggests that explanatory questioning can facilitate learning and is effective across different contexts. For example, elaborative interrogation effects can be seen in learning conditions such as incidental or intentional learning instructions (Woloshyn, Willoughby, Wood, & Pressley, 1990), and among students working individually, in dyads, and in small groups (Woloshyn & Stockley, 1995). Students' characteristics such as high and low knowledge domains are explored in examining the effects of elaborative interrogation on learning outcomes as well. Woloshyn, Pressley, & Schneider (1992) presented Canadian and German students with facts about Canadian provinces and German states. The facts were facilitated by answering the questions such as "Why does that make sense given what you know about that particular province?" tapping into the prior knowledge. Students in the study showed larger effects of elaborative interrogation in their high-knowledge domain than in their low-knowledge domain (Woloshyn et al., 1992).

Although most of the studies applied elaborative interrogation to discrete units of factual information, effects have also been shown in longer connected discourse (Dunlosky et al., 2013). Seifert (1994) found that elaborative interrogation significantly improved students' memory of facts contained in prose paragraphs. McDaniel and Donnelly (1996) examined the effectiveness of a variety of techniques—analogy, analogy with keyword highlighting, labeled pictorial schematics, and elaborative interrogation for enhancing newly acquired scientific concepts directly contrasting their relative effectiveness. The results showed that elaborative interrogation produced substantial learning gains both factual-level and inference-level

performance.

An important cognitive factor associated with the use of elaborative interrogation is that learners activate what Willoughby and Wood (1994) call "schemata" that help to organize new information that facilitates retrieval. The literature also points to learners being able to discriminate among related facts when identifying or retrieving newly learned information. This aspect is highlighted in Hannon's (2012) study, which distinguishes between integrative and comparative elaborations and argues that these variations seem to have different cognitive mechanisms. In integrative elaborations, for example, asking learners to generate how new themes or ideas in the text relate to one another may help activate and structure their conceptual knowledge. Similarly, in comparative elaborations, asking learners to compare pairs of examples which vary in quality facilitates the activation level of "critical distinctive" features in the memory trace of each concept making each memory trace more unique and complex (Hannon, 2012).

To summarize, there is a clear link between the cognitive mechanisms that promote learning based on prompting learners to explain their understanding and learning goals in a variety of different contexts. The strategy helps learners activate their cognitive processes of understanding by activating their prior knowledge, checking for gaps in their understanding, focusing on information that is new or unclear to them, and relating, organizing, and restructuring newly learned information (King, 1991; Palincsar & Brown, 1984; Willoughby & Wood, 1994; Willoughby, Wood, & Khan, 1994; Woloshyn et al., 1992). In the context of the present study, these mechanisms associated with the elaborative interrogation prompts are likely to promote synthesis of ideas in a number of ways—engaging their prior knowledge about the topic, noting gaps in their understanding, linking new ideas and themes from multiple sources, and structuring their conceptual understanding of the topic.

3 Methodology

Upon approval by the Institutional Review Board, the participants were recruited using Amazon's Mechanical Turk (AMT). Started in 2005, AMT provides a crowdsourcing web service platform to recruit participants for research studies involving surveys and experiments in exchange for small wages. The platform allows researchers to set predefined criteria to recruit subjects (workers) to perform these Human Intelligence Tasks (HITs) (Paolacci, Chandler, & Ipeirotis, 2010). One hundred and twenty slots were created for the experiment—40 for each condition of the experiment. The experimental task was designed in Qualtrics as three surveys representing each experimental condition and implanted in AMT as a URL link. Each survey link was embedded in AMT as a task representing each condition of the experiment. The participants completed only one of the three embedded tasks in AMT.

The researcher set the recruitment criteria to include participants from the United States only along with a prior task approval rating of at least 70%. The prior approval rate allows requesters to recruit workers who have successfully completed HITs in the past. For example, if a worker has completed 100 HITs and had their work rejected 5 times, their approval rate is 95%. The participants received $1.00 upon successful completion of the experimental task. The financial support for the project came from the funds allocated for graduate students' research projects at the college level.

Participants were given instructions in each of the three conditions about the topic and were instructed to read the five texts (for each experimental condition), respond to elaborative prompts (treatment conditions only), and then write a paragraph that synthesizes the information (all three conditions). Three conditions were as follows:

1. Elaborative interrogation prompts (EP-treatment group): Participants in this condition typed their responses to elaborative interrogation prompts that are embedded after each individual text.
2. Elaborative interrogation prompts with reverse order of texts (EP-RO-treatment group): Participants in this condition typed their responses to elaborative interrogation prompts that are embedded after each individual text presented in reverse order to minimize order effects bias (Whitley & Kite, 2013).
3. No elaborative interrogation prompts (C-control group): Participants in this group read the provided texts with no prompts.

Information sources on the topic of climate change were used with permission from a multiple documents comprehension study conducted by Strømsø, Bråten, & Britt (2010). The topic was chosen because it lent itself to constructing an argument.

The task was made available to the participants in AMT as "learning about climate change" for each of the experimental conditions. It was also speculated that the prior interest of participants in climate change, as well as their educational level, would impact their transformation and integration performance. In order to address a potential confounding effect, prior interest in climate change and educational level were treated as covariates in the statistical model. Prior interest in climate change was measured on a scale of 1-10, 1 representing least interest, and 10 representing most interest. The level of education was measured on a scale of 1-6, 1 representing some high school, no diploma, 2 representing high school graduate, diploma or the equivalent, 3 representing some college credit, no degree, 4 representing associate degree, 5 representing bachelor's degree, and 6 representing master's or doctorate degree. It is important to note that prior research designs involving comprehension and integration using multiple documents (Gil et al., 2010; Strømsø et al., 2010) measured and adjusted for the interaction effects of prior knowledge. However, the participants in these studies were first-year undergraduate students enrolled in introductory courses and the experiments were conducted in multiple sessions with an interval of 2 days. First, the participants were administered the prior knowledge measure. In the second session, participant performed the experimental tasks. The participants in the present study were recruited through an online platform (AMT) and completed the experimental tasks during a single session. In addition, the emphasis in the present study was on the effect of elaborative interrogation prompts—with one of the prompts "What do you already know about the topic?" (Table 1. *Description of Steps in the Procedure*) which served the function of engaging participants' prior knowledge of the topic. In contrast, the level of interest in the topic and level of education were treated as covariates. Adding another session prior to the experimental tasks of reading the texts, responding to the elaborative interrogation prompts, and composing a synthesis essay would have significantly increased the cognitive load for the participants.

Once the task was accepted, the participants clicked on the embedded Qualtrics survey link in AMT. The experimental procedure in Qualtrics is described in Table 1 below, highlighting the cognitive functions associated with each step.

Table 1. Description of Steps in the Procedure

Steps	Description	Function
1. Topic Introduction	Introduction to the task and topic description (Appendix B)	Introduces the topic and task to the participants
2. First Set of Elaborative Interrogation Prompts (1.1 and 1.2 Treatment Group)	1.1 "What do you already know about the topic?" 1.2 "What questions come to your mind after you have read the topic description?" 1.3 "On a scale of 1-10, (1 representing least interest, and 10 representing most interest), how interested are you in the topic of climate change?" (1.1 and 1.2 for treatment group only and 1.3 for both groups)	Engages prior knowledge of the topic. Level of interest serves as a covariate
3. Presentation of Texts	The five texts were introduced as "Text 1" "Text 2" etc. without any descriptors.	Develops participants' understanding of the key issues and concepts associated with climate change
4. Second Set of Elaborative Interrogation Prompts (Treatment Group)	2.1 "As you examine this source, what new themes emerge about the topic?" "How are these themes related to what you read in other sources?" (Second prompt embedded in second and subsequent texts)	Drives paraphrase, elaboration, and addition cognitive mechanisms
5. Synthesis Essay	Participants in all groups composed their synthesis paragraphs after reading the texts.	Synthesis essay coded for measures of transformation and integration measures (Table 6)

The coding scheme for the various dependent measures was based on Gil et al. (2010) which examined summary and argumentative tasks in the context of working with multiple documents. The coding scheme consists of two main categories: transformation and integration. Transformation includes the sub-categories paraphrase, elaboration, addition, and misconception; and integration includes the sub-category number of texts and number of switches between sources, as described in Table 2.

Table 2. Operational Definitions of the Writing Measures

Main Category	Sub-category	Description
Transformation (P + E + A - M)	Paraphrase (P)	Student states text content in their own words without changing meanings expressed in the source material
	Elaboration (E)	Student uses source material in combination with information from prior knowledge or combines two or more pieces of information within or across texts
	Addition (A)	Student includes related information from prior knowledge or states personal opinion about the topic
	Misconception (M)	Student includes statements indicating misunderstanding of the content of the source material
Integration (T + S)	Number of texts (T)	Number of different sources used
	Number of switches (S)	Number of switches between sources

Note: Adapted from Gil et al. (2010).

The results from treatment conditions that did not include responses to the elaborative prompts after each text were excluded from the analysis. Similarly, responses that contained irrelevant content not related to climate change were also excluded.

In tasks that require learners to write arguments or summaries from multiple sources (Chi et al., 1994; Coté et al., 1998; Rouet et al., 1996; Wiley & Voss, 1999; Wolfe & Goldman, 2005), student essays are segmented into idea units, often at the sentence level, containing one or more related items of information. As prescribed by the original coding scheme (Gil et al., 2010), each idea unit was coded as representing one of four types of transformation of the original text—either paraphrase, elaboration, addition, or misconception to calculate the overall transformation score. It should be noted here that in Gil et al. (2010) study, the authors decided to award two points for each elaboration (P + E + 2A - M) because elaborations were considered to carry a greater degree of transformation compared to both paraphrases and additions. However, in this study, the author decided to put equal weight on all three sub-measures of transformation (P + E + A - M).

Idea units were coded as paraphrases if the respondents used their own words without changing the meaning expressed in the text. For example, *"The increase in the release of carbon dioxide into the atmosphere has caused an increase in the temperature of the earth."* Idea units were coded as elaborations if they contained information from the text in combination with some information from prior knowledge or if they combined two or more pieces of information either within or across texts, which were not connected in the source. For example, *"The warming of the climate causes farming and forestry to become affected, as extreme warming can lead to extreme cold spells causing crop damages that hurt local populations and wildlife."* Idea units were coded as additions if they contained only related information from prior knowledge or personal opinions about climate change. For example, *"The increasing use of fossil fuels has to be stopped, as if we don't, we will continue to experience harsh consequences (these hurricanes, Harvey and Irma) as a result of our continued ignorance and unwillingness to refute fossil fuels."* Idea units were coded as misconceptions if they contained false statements or misunderstanding in relation to the information in the original texts. For example, *"The global average temperature today is about 15C, though geological evidence suggests it has been much higher and lower in the past."*

In terms of integration, the goal was to identify the text with each idea unit in the synthesis paragraphs and count the number of different texts that the respondent used in their writing. For example, a score of five suggests that the response included all five texts and a score of zero suggests a lack of coverage of original texts. In addition, the number of switches between texts were counted. For example, if a response contained ten idea units and the first three idea units came from text 1, the next five came from text 2, and the last two came from text 3, it was counted as two switches. The aggregate score for the integration measure was calculated by adding the number of texts used and number of switches between texts.

A random subset of 20 responses, which accounted for over 20% of the total after excluding responses based on the exclusion criteria described previously, were coded independently by the researcher and one experienced writing instructor using the coding scheme described in Table 6, resulting in the overall interrater agreement of 74% for the transformation measure and 89% for the integration measure. All disagreements in coding were discussed between the two raters to gain more insight into interpretation of the coding scheme. Once agreement was established, the researcher coded the entire remaining data set.

The number for each sub-category measure such as paraphrases, elaborations, additions, and misconceptions were calculated along with the number of total words and sentences in the synthesis paragraphs. After the synthesis essays were coded, an aggregate score for each condition for both transformation and integration measures were calculated and the resulting data set was used to perform descriptive and inferential analysis.

4 Results

The preliminary analyses included the calculation of descriptive statistics for the performance of participants, independent of condition, as assessed by 10 variables. The objective of this analysis was twofold. First, the identification of minimum and maximum values for each variable facilitated the interpretation of subsequent descriptive and inferential analyses. Secondly, the calculation of means and standard deviations allowed the researcher to assess the variation of scores, which is especially desirable in experimental research designs (Pallant, 2016). As shown in the following table, high standard deviations were observed in all variables, suggesting that mean values are dependent on certain factors; hopefully on the introduction of elaborative interrogation prompts (Table 3).

Hypothesis 1. In order to explore if there is a statistically significant effect of elaborative interrogation prompts on transformation performance, while controlling for a potential effect of prior interest in climate change and educational level, a one-way ANCOVA was conducted. Contrary to the expectations, an initial descriptive analysis showed that control group performed slightly better than treatment groups, whereas EP-RO treatment group reported the lowest mean transformation scores (Figure 1).
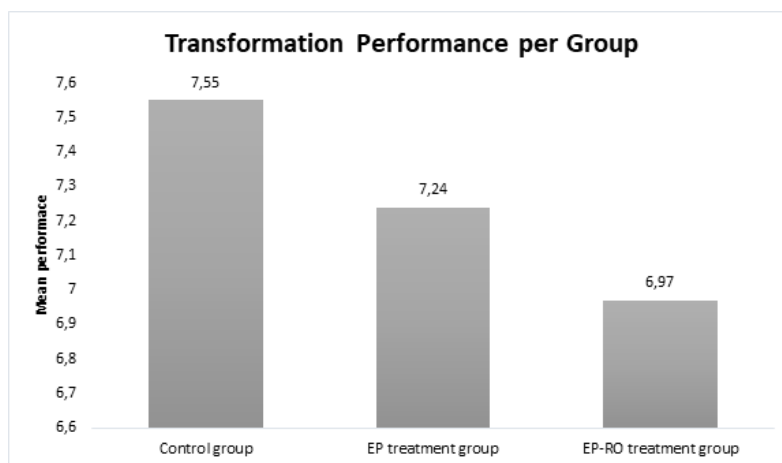

Figure 1. Mean differences in transformation performance among groups.

After adjusting for interest in climate change and educational level, a one-way ANCOVA indicated a non-statistically significant effect of condition on transformation outcomes, $F(2, 81) = .39$, $p = .67$, $\eta_p^2 = .010$, with the same pattern of mean differences being observed (Table 4).

Table 3. Descriptive Analysis on Variables Assessing Transformation and Integration Performance

	Minimum	Maximum	M	SD
N of words	30	625	141.59	85.71
N of sentences	2	17	7.31	3.45
N of paraphrases	0	14	2.58	3.32
N of elaborations	0	12	1.92	2.29
N of additions	0	12	2.73	2.72
N of misconceptions	0	1	.06	.24
N of texts	0	5	2.81	1.39
N of switches	0	7	2.07	1.49
Overall transformation score	2	17	7.26	3.49
Overall integration score	0	12	4.88	2.82

Table 4. Unadjusted Condition Means (M) and Standard Deviations (SD) and Adjusted Condition Means (M) and Standard Errors (SE) for Transformation Performance with Interest in Climate Change and Educational Level as Covariates

		Unadjusted		Adjusted	
	n	M	SD	M	SE
Control condition	31	7.55	3.56	7.67	.62
EP-treatment condition	25	7.24	3.89	7.06	.69
EP-RO treatment condition	30	6.97	3.15	6.97	.62

In reference to the relationship of covariates with transformation performance, results revealed a statistically significant relationship between interest in climate change and transformation, $F(1, 81) = 5.27$, $p =$

.024, $\eta_p^2 = .061$, suggesting that higher levels of interest in climate change are related to higher transformation performance. Nevertheless, the small effect size reported is indicative of a rather weak relationship. Lastly, a non-statistically significant relationship between educational level and transformation, $F(1, 81) = 1.78$, $p = .19$, $\eta_p^2 = .021$, was observed.

To summarize the primary findings, a descriptive analysis showed that participants in control group achieved a slightly better performance in transformation, as compared to participants in treatment groups. In addition, a one-way ANCOVA indicated that the presentation of elaborative interrogation prompts did not exert a significant amount of influence on transformation measure. Therefore, hypothesis 1 is not supported.

Hypothesis 2. In order to explore if there is a statistically significant effect of elaborative interrogation prompts on integration performance, while accounting for a potential effect of interest in climate change and educational level, a one-way ANCOVA was conducted. In accordance with the expectations of the researcher, a preliminary descriptive analysis showed that treatment groups performed better than control group and EP-RO treatment group reported the highest integration scores (Figure 2).
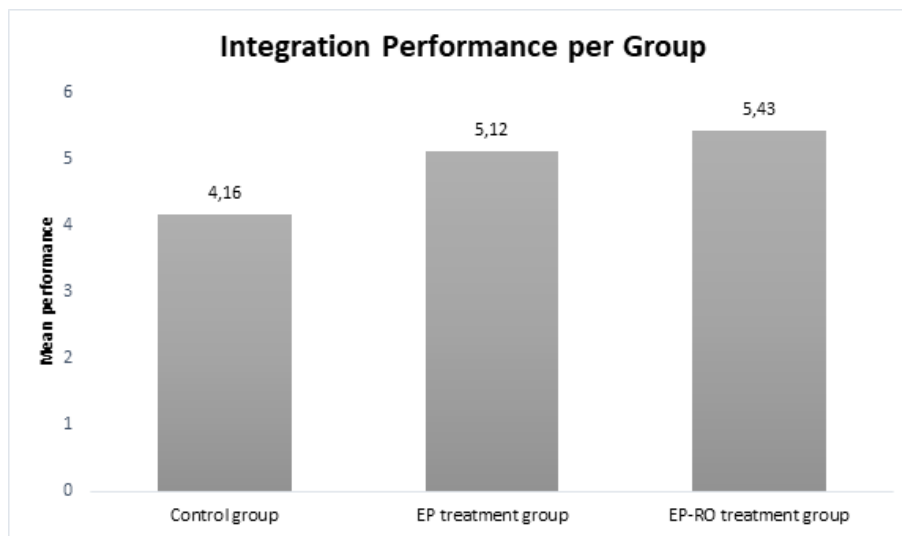

Figure 2. Mean differences in integration performance among groups.

After adjusting for interest in climate change and educational level, a one-way ANCOVA indicated a non-statistically significant effect of condition on integration outcomes, $F(2, 81) = 1.43$, $p = .25$, $\eta_p^2 = .034$, with the same pattern of mean differences being observed (Table 5).

Concerning the relationship of covariates with integration performance, a non-statistically significant relationship between pre-existing interest in climate change and integration, $F(1, 81) = .027$, $p = .87$, $\eta_p^2 < .001$, was observed. However, results revealed a statistically significant relationship between educational level and integration, $F(1, 81) = 4.31$, $p = .041$, $\eta_p^2 = .051$, denoting that higher levels of education are related to higher integration performance. Nevertheless, a small effect size was reported, which is indicative of a rather weak relationship.

Conclusively, a descriptive analysis showed that participants in treatment conditions achieved a better performance in integration than participants in control group. Nevertheless, a one-way ANCOVA revealed that the presentation of elaborative interrogation prompts did not significantly impact integration measure. Therefore, hypothesis 2 is not supported.

Table 5. Unadjusted Condition Means (M) and Standard Deviations (SD) and Adjusted Condition Means (M) and Standard Errors (SE) for Integration Performance with Interest in Climate Change and Educational Level as Covariates

		Unadjusted		Adjusted	
	n	*M*	*SD*	*M*	*SE*
Control condition	31	4.16	2.51	4.23	.50
EP-treatment condition	25	5.12	2.96	5.09	.56
EP-RO treatment condition	30	5.43	2.94	5.39	.51

5 Discussion

Contrary to what was hypothesized, the results from the descriptive analysis showed that the participants' performance was slightly better on transformation measure in the control group. A logical explanation of this could be the extra time and cognitive effort spent in both treatment groups (EI and EI-RO) to respond to the prompts after each text compared to no prompts in the control group, thereby giving participants more time to write the synthesis paragraphs. Responding to prompts after each text is cognitively taxing. In previous multiple documents studies (Gil et al., 2010), this may also suggest that the cognitive mechanisms that process multiple information sources are complex and require a sustained and distributed effort.

One of the limitations of this design is that it represents only one of many ways of presenting multiple texts to gather information and synthesize ideas, thus limiting the ecological validity of the study (Perfetti et al., 1999, Whitley & Kite, 2013). There are a variety of platforms and manifestations, both print and digital, that participants may have been more used to when using multiple sources of information.

In addition, it is difficult to pay sustained attention to a task involving a variety of increasingly cognitively demanding steps that include reading, reflecting, and writing based on the provided content—embedded in an online survey platform in a short period of time. Higher-order cognitive tasks such as integration and transformation of ideas investigated in this study demand considerably higher level of sustained engagement, focus, and concentration compared to other tasks such as taking part in short surveys and questionnaires.

Similarly, Buhrmester et al. (2011) note that another limitation to AMT is the lack of opportunity to exert control over participants' environment compared to lab studies. Controlling for time taken to complete the assigned sub-tasks such as time spent on each text and time allocated for writing the synthesis paragraph were beyond the researcher's control in the present study.

The topic of climate change was well-suited for the study as it lends itself to writing a short synthesis piece. The presentation of scientific information has been demonstrated to facilitate conceptual change (Ranney & Clark, 2015). However, climate change is also a politically charged topic and despite the researcher's attempt to select the texts from a previous research study, the possibility that participants may have selectively focused on texts that contained information that they considered most important or reflected their prior understanding or stance on the topic is still a concern.

6 Implications for Practice and Future Research

The study focused on short sources of information on the topic of climate change, further research is needed to examine the effect of elaborative prompts under different tasks and topics that involve comprehension, integration, and transformation other than climate change. Using texts and coding scheme from prior

research studies in multiple documents comprehension helped provide experimental control in terms of research design. However, starting from scratch with another topic would involve selecting texts, reading and identifying key idea units within each text, and creating similar coding schemas might prove to be daunting tasks from the practitioners' standpoint. Conversely, developing an assessment based on a similar coding scheme might provide a more robust measure of synthesis than a generalized rubric-based assessment (Oakleaf, 2008).

The individual amount of time spent on each text was not measured in this study. The research assumes that participants spent roughly the same amount of time on each text. Future research needs to examine and control for this important variable in assessing overall integration and transformation. Triangulating the assessment of synthesis with other methods such as think-aloud, screencasts, eye-tracking, and other log data measures would further develop this line of research.

As prior research on multiple documents comprehension illustrates, the cognitive processes that scaffold the synthesis of ideas are not well understood (Rouet, 2006). It presents unique challenges for researchers especially in terms of acknowledging the familiarity with the platform, format, medium of presentation of documents, level of interest, imposed vs. self-generated inquiry, and prior knowledge. As noted in the methodology section, prior research has shown the interaction effects of prior knowledge involving comprehension and integration tasks using multiple documents (Gil et al., 2010; Strømsø et al., 2010). Despite methodological challenges (multiple sessions, reliability of the prior knowledge measure, choice of experimental platform, participants' sample, cognitive overload, experimental fatigue, primacy/ recency effects), the degree to which the effect of elaborative interrogation technique generalizes across experimental conditions controlling for prior knowledge need to be further examined. Assessment of a shape-shifting ghost such as synthesis of ideas from multiple documents is full of contextual factors that determine how learners interact with and gather information from an increasingly complex information landscape. Considering these limitations, future research needs to draw from other non-overlapping bodies of literature that provide both theoretical grounding and refine research methods to examine this problem more holistically.

The present study contributes to the growing body of literature on the new Framework, its associated knowledge practices, and ways to develop pedagogical and assessment approaches. In addition, the study contributes to the literature on multiple documents literacy, effective learning techniques, and application of learning science principles to facilitate the growth on the information literacy continuum. The cognitive benefits of learning techniques such as explanations, analogies, highlighting, summarizing, and practice testing (Dunlosky, 2013), lend themselves to further exploration to help learners cross these information literacy threshold concepts in the Framework (ACRL, 2016). Factual, inference, and synthesis level performance indicators are outlined in the each of the frames in the Framework, but are particularly relevant to the "Research as Inquiry" frame which emphasizes information seeking as an iterative, complex process (ACRL, 2016). The learners who are developing these abilities reexamine their information gaps, assess strengths and weaknesses of sources they encounter, organize and synthesize information gathered from multiple sources in meaningful ways (ACRL, 2016). There are several practical implications that emerge from this line of research. Information literacy instruction based on the new Framework can benefit from recommendations about the relative utility of other learning techniques in general, and elaborative interrogation in particular. Using a combination of these techniques and examining their relative utility across not just a variety of knowledge practices and dispositions but also acknowledging the effects of other variables such as learning conditions (synchronous, asynchronous, hybrid learning environments), student characteristics (age, ability, prior knowledge) on information seeking tasks and behaviors (formulating, searching, evaluating, synthesizing) will benefit information literacy instruction and assessment. In addition, exploring disciplinary differences and development of specialized information skills through the intersection of effective learning science principles and the Framework might help educators design learning experiences that facilitate the metacognitive engagement with information tasks as learners move on the continuum from novice to expert information users.

7 Conclusion

The primary objective of this study was to examine and align one of the key knowledge practices in the new Framework—the ability to synthesize ideas gathered from multiple sources of information with an appropriate learning technique—elaborative interrogation. The individual frames highlight the threshold concepts learners experience as they navigate a complex, uncertain, and evolving information ecosystem. The shift from previous skill-based, mechanistic standards has amplified the need to draw tangential connections with cognitive and learning science principles and advance new ways to effectively develop curriculum for information literacy and assess learners' performance as they improve their understanding of these knowledge practices and navigate these threshold concepts. The interconnected threshold concepts in the Framework represent a move away from prescriptive outcomes and skills, and the nebulous and abstract nature of these concepts presents challenges for both practitioners and researchers. The synergy between research and practice is what is urgently needed in the profession—a long-term research-practice collaboration that provides practitioners a theoretical grounding for the praxis of information literacy instruction.

Just as the Framework represents a renewed approach to conceptualizing information literacy, this line of research represents a new focus on aligning effective learning and assessment techniques, acknowledging behavioral, affective, cognitive, and metacognitive dimensions of learning. The introduction of the Framework has prompted the much needed dialogue between research and practice to examine the theoretical assumptions of teaching and learning and it is the researcher's hope that this work will further engage colleagues from both sides to develop evidence-based recommendations for information literacy instruction.

References

Association of College and Research Libraries (ACRL). (2016). *Framework for information literacy for higher education*. Retrieved from http://www.ala.org/acrl/sites/ala.org.acrl/files/content/issues/infolit/Framework_ILHE.pdf

Buhrmester, M., Kwang, T., & Gosling, S. D. (2011). Amazon's Mechanical Turk: A new source of inexpensive, yet high-quality, data? *Perspectives on Psychological Science*, *6*(1), 3-5. doi:10.1177/1745691610393980

Chi, M. T., De Leeuw, N., Chiu, M. H., & Lavancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, *18*(3), 439-477. doi:10.1016/0364-0213(94)90016-7

Coté, N., Goldman, S. R., & Saul, E. U. (1998). Students making sense of informational text: Relations between processing and representation. *Discourse Processes*, *25*(1), 1-53. doi:10.1080/01638539809545019

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*(1), 4-58. doi:10.1177/1529100612453266

Gil, L., Bråten, I., Vidal-Abarca, E., & Strømsø, H. I. (2010). Summary versus argument tasks when working with multiple documents: Which is better for whom? *Contemporary Educational Psychology*, *35*(3), 157-173. doi:10.1016/j.cedpsych.2009.11.002

Goldman, S. R., Braasch, J. L., Wiley, J., Graesser, A. C., & Brodowinska, K. (2012). Comprehending and learning from Internet sources: Processing patterns of better and poorer learners. *Reading Research Quarterly*, *47*(4), 356-381. doi:10.1002/RRQ.027

Hannon, B. (2012). Differential-associative processing or example elaboration: Which strategy is best for learning the definitions of related and unrelated concepts? *Learning and Instruction*, *22*(5), 299-310. doi:10.1016/j.learninstruc.2011.11.005

King, A. (1991). Improving lecture comprehension: Effects of a metacognitive strategy. *Applied Cognitive Psychology, 5*(4), 331–346. doi:10.1002/acp.2350050404.

McDaniel, M. A., & Donnelly, C. M. (1996). Learning with analogy and elaborative interrogation. *Journal of Educational Psychology*, *88*(3), 508.

Oakleaf, M. (2008). Dangers and opportunities: a conceptual map of information literacy assessment approaches. *Portal: Libraries and the Academy*, *8*(3), 233-253. doi:10.1353/pla.0.0011

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension–Fostering and comprehension–Monitoring activities. *Cognition and Instruction, 1*(2), 117-175.

Paolacci, G., Chandler, J., & Ipeirotis, P. G. (2010). Running experiments on Amazon Mechanical Turk. *Judgment and Decision Making*, *5*(5).

Pallant, J. (2016). *SPSS survival manual* (6th ed.). Maidenhead: McGraw-Hill Education.

Perfetti, C. A., Rouet, J. F., & Britt, M. A. (1999). Toward a theory of documents representation. In H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 99-122). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Ranney, M. A., & Clark, D. (2016). Climate change conceptual change: Scientific information can transform attitudes. *Topics in Cognitive Science*, *8*(1), 49-75. doi:10.1111/tops.12187

Rouet, J. F. (2006). *The skills of document use: From text comprehension to Web-based learning*. Psychology Press.

Rouet, J. F., Britt, M. A., Mason, R. A., & Perfetti, C. A. (1996). Using multiple sources of evidence to reason about history. *Journal of Educational Psychology*, *88*(3), 478-493.

Seifert, T. L. (1994). Enhancing memory for main ideas using elaborative interrogation. *Contemporary Educational Psychology*, *19*(3), 360-366. doi:10.1006/ceps.1994.1026

Strømsø, H. I., Bråten, I., & Britt, M. A. (2010). Reading multiple texts about climate change: The relationship between memory for sources and text comprehension. *Learning and Instruction*, *20*(3), 192-204. doi:10.1016/j.learninstruc.2009.02.001

Whitley, B. J., Kite, M. E., & Adams, H. L. (2013). *Principles of research in behavioral science*. New York, NY: Psychology Press.

Wiley, J., & Voss, J. F. (1999). Constructing arguments from multiple sources: Tasks that promote understanding and not just memory for text. *Journal of Educational Psychology*, *91*(2), 301.

Willoughby, T., & Wood, E. (1994). Elaborative interrogation examined at encoding and retrieval. *Learning and Instruction*, *4*(2), 139-149. doi:10.1016/0959-4752(94)90008-6

Willoughby, T., Wood, E., & Khan, M. (1994). Isolating variables that impact on or detract from the effectiveness of elaboration strategies. *Journal of Educational Psychology*, *86*(2), 279-279. doi:10.1037//0022-0663.86.2.279

Wolfe, M. B., & Goldman, S. R. (2005). Relations between adolescents' text processing and reasoning. *Cognition and Instruction*, *23*(4), 467-502. Retrieved from https://www.jstor.org/stable/3568111

Woloshyn, V. E., Willoughby, T., Wood, E., & Pressley, M. (1990). Elaborative interrogation facilitates adult learning of factual paragraphs. *Journal of Educational Psychology*, *82*(3), 513-524. doi:10.1037/0022-0663.82.3.513

Woloshyn, V. E., Pressley, M., & Schneider, W. (1992). Elaborative-interrogation and prior-knowledge effects on learning of facts. *Journal of Educational Psychology*, *84*(1), 115-124.

Woloshyn, V. E., & Stockley, D. B. (1995). Helping students acquire belief-inconsistent and belief-consistent science facts: Comparisons between individual and dyad study using elaborative interrogation, self-selected study and repetitious-reading. *Applied Cognitive Psychology*, *9*(1), 75-8. doi:10.1002/acp.235009010